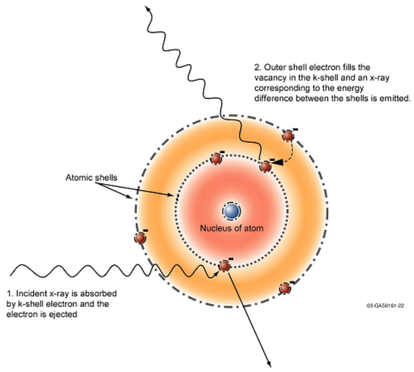
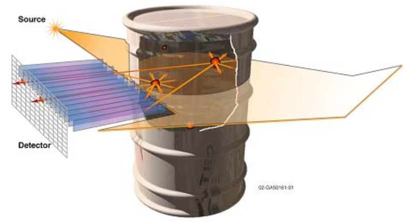
DRCT Laboratory
X-Ray Fluorescence (XRF) Imaging

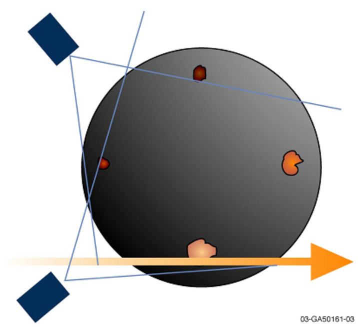
X-ray fluorescence is a physical process in which an atom absorbs energy from one x-ray and emits an x-ray at another energy. The energy of the emitted x-ray is characteristic of the element in which the interaction occurred. Analysis of the spectra of emitted x-ray energies can be used to determine the elemental contents of a suspect package or waste drum.





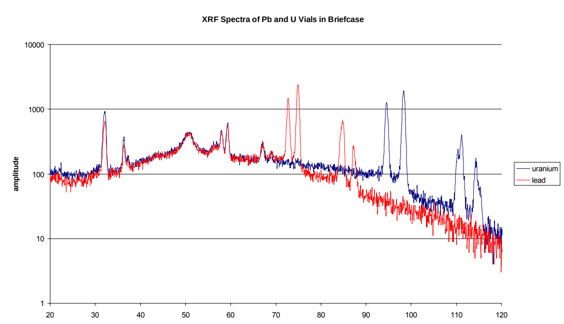
X-ray fluorescence spectroscopy could be used to interrogate waste containers to determine, and possibly quantify, heavy metal or transuranic content. One method, shown above, would be to irradiate the entire container with x-rays and detect the induced fluorescence with a segmented, spectroscopic x-ray detector. Each “pixel” in the detector array would be collimated and a three dimensional map of XRF emitters could be obtained through rotate and translate protocols. Alternatively, conventional x-ray transmission images acquired with the same x-ray source may be used to guide XRF detection to a region of interest.

A pencil beam of x-rays can be used to collect first generation CT data by collecting XRF spectra as the sample is translated and rotated through the beam. Energy windows around peaks in the spectra can be processed into sinograms (see below) that are used to create the tomographic reconstructions. Each tomographic slice is an image of the same physical cross section of the object but is reconstructed using a different energy and thus represents a different material.



The object used to test the XRF CT system consists of a plastic (low-density) container holding four vials. The vials contain uranium oxide, mercury chloride, lead, and tantalum. A reconstructed image is shown on the right

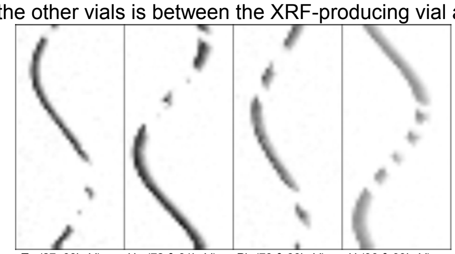
Radiograph of a laptop computer in a briefcase. In the lower left of the image, two vials can be seen. The right vial is nearly full of lead shot and the left one is partially full of uranium oxide. The gray levels of the images have been modified to make these objects more obvious. The vials are about the size and shape of the batteries in the battery pack in the upper left corner of the computer.



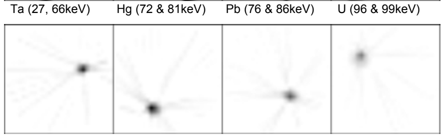
X-ray energy spectra collected when the probe beam from the x-ray generator is aimed at two different regions of the briefcase. For the blue line, the probe beam was aimed at the small vial of uranium. For uranium, the XRF K-α lines are at 95.7 and 98.5 keV and the K-β lines are at 110.4 and 111.3 keV. The beam was aimed at the vial of lead to generate the data for the red line. For lead, the the XRF K-α lines are at 75.0 and 99.0 keV and the K-β lines are at 84.5 and 84.9 keV. Automated processing discriminates between spectra from different materials of interest.

Sinograms

A sinogram is a 2D visualization of CT data before reconstruction. For a first-generation CT scan, the horizontal dimension of the sinogram represents the translational position of the sample and the vertical dimension of the sinogram represents rotational angle. The pixel intensity in the sinogram is proportional to the number of counts collected at that translate/rotate position. The counts will be high when the x-ray beam intersects one of the samples and should be zero otherwise. In the figure, each sinogram represents data collected at energies that are characteristic of the XRF of one element only. The sinograms should be continuous sine-shaped curves. The discontinuities in the curves are due to attenuation of the XRF by one of the other vials in geometries where one of the other vials is between the XRF-producing vial and the detector.



Ta (27, 66keV) Hg (72 & 81keV) Pb (76 & 86keV) U (96 & 99keV)



Tomographic data from different energy windows can be reconstructed to create a cross-sectional image in which the pixel intensity is proportional to the amount of material that fluoresces in that window. Thus an image of the distribution of each element in the object can be created. The summed image shows the relative locations of the heavy metals in relation to each other.